The Science of Team Science

Commentary on Measurements of Scientific Readiness

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Introduction

Some topics in this supplement to the *American Journal of Preventive Medicine*[1–3] focus on the rigorous analysis of various contextual factors influencing the design, implementation, and sustainability of transdisciplinary research; however, an additional area of scientific exploration that may benefit Team Science and the transdisciplinary research field is the formal investigation of factors that elucidate when scientific areas are merging and/or ripe for collaborative study. This precursor of collaboration readiness could play a significant role in understanding why and how team science collaborations breakdown or thrive.[1] If fields of science have not sufficiently evolved toward one another or their underlying support structures are incongruous, it may be difficult or impossible to initiate and maintain cross-disciplinary research even though the participants are eager and other readiness challenges have been successfully met. Understanding the underlying *readiness* markers could go a long way in determining why some collaborative projects fail or succeed, forecasting why and/or when some projects should be initiated, and identifying collaborative opportunities that were otherwise unknown. These findings could be used to help identify research opportunities within and across scientific fields. After gaining insight into when scientific areas are converging, having tools or methodologies for matching compatible investigators for successful Team Science would further aid the process.

The following commentary, from an outside, but interested, observer of the transdisciplinary research field, focuses on a generalized interpretation of two potential serial phases of team science. These phases do not cover the breadth of research being done on the science of team science, but instead highlight arenas of research that might add potentially significant domains of inquiry.

Phase 1

→ Investigators determine that a team-science approach might benefit their research.
→ Funding organizations look for new, emerging, or innovative approaches to research that could increase the potential for more, improved, or quicker research outcomes.

Study elements. Investigate the metrics or identifiers that are used or could be used by researchers and funding organizations to determine when areas of science are ripe for collaborative research and, more specifically, transdisciplinary research.

One of the initial challenges for Phase 1 is to identify good metrics or science markers that can demonstrate connections between fields of research. Some metrics might include markers of when: (1) two scientific fields share system pathways or molecular components, (2) the scientific methodologies overlap in some key way, or (3) the conceptual research questions or ideology are the same (e.g., studying the genetic drivers for reproductive behavior across plant and animal species). The next step would be to determine when the metrics identify fields of research, narrow or broad, that are converging or have overlap. Based on findings derived from analyses hypothesized above, can these metrics be used to determine whether the research areas are ready for collaborative investigation?

Companies, publishers, and organizations have already begun developing technologies (e.g., research profiling[4–6]) that can mine elements of research including published articles to assist in identifying when, for example, similar words or concepts (e.g., proteins or methodologies) begin to appear in historically unrelated fields of research. However, more investigative work needs to be done on whether the overlap of a few concepts, citation connections (bibliometrics[7]), or methodologies is sufficient and predictive of merging areas of science and additionally whether these areas of science would benefit from collaborative research. Nonetheless, the development of these tools will likely have benefit for most scientists in their attempt to understand the ever expanding number of research papers and information being collected and published. Without the emergence of these tools, one can envision researchers moving toward microcosm fields of expertise, narrowing their scientific scope to help establish or maintain clear parameters for what constitutes the body of knowledge they can justifiable defend.

An initial area of inquiry for scientific readiness might include a review of successful and unsuccessful transdisciplinary research (or add questions to any

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Published by Elsevier Inc. doi:10.1016/j.amepre.2008.05.016

similar review studies that may already be underway). An understanding about the scientific events that led to the collaborative efforts and any scientific-readiness cues that were employed could provide insight that may well be used more systematically to establish successful teams. Using models or novel approaches based on these metrics of scientific readiness, as associated with successful or unsuccessful collaborative research projects, could provide suggestive information about when the opportunity for research collaboration is ripe.

This line of thought leads to additional questions such as: (1) What new analytical tools could assist in our understanding of readiness cues? (2) Are there hindrances to accessing the data needed for proper analyses, developing models, or testing hypotheses? For example, would a uniform interface with access to all journal articles (or summaries) be necessary for practical, comprehensive data mining by investigators and funding organizations to unearth connections? Access to research descriptions, publications, data sets, and methodology repositories, for example, may prove essential for capturing the proper metrics. (3) Can new technologies be transformative in the way we identify collaborative areas of research? (4) Will the output of these tools provide more refined definitions of what constitutes relatedness (e.g., related papers, findings, or researchers) in a way that is now very difficult due to both the sheer abundance of scientific information and the difficultly in connecting the information from disparate locations or repositories?

If these tools are successful in identifying scientific convergence, investigators and funding organizations will next need to know which researchers in the respective fields are the most appropriate for establishing a team to move the science forward.

Phase 2

→ Investigators use various methods to identify a researcher with the right expertise and compatibility to initiate a research partnership.
→ Funding organizations use various methods to identify the "right" researchers who can carry out successful (transdisciplinary or collaborative) research when Phase 1–type opportunities appear to exist.

Study elements. Investigate the metrics or identifiers that an investigator or funding organization uses or could use to determine who the best collaborator(s) would be for their conceptualized research idea. Investigate which metrics or combination thereof could serve as forecasters of successful collaboration. Determine the best methods to bring together disciplines and people when areas of science have been identified as promising for transdisciplinary or team research.

Previous research findings on the contextual issues related to the science of team science are likely to offer insights into what tools could further benefit the process of linking the right investigators. For example, should there be a broad researcher database or connected set of databases that serve as communities of practice (CoP[8])? These CoPs could incorporate not only an investigator's research publications but also their current contact information, their self identified expertise and interests, and possibly recommendations or comments from other researchers. This proposition is not new and available tools are already appearing on the Internet (some specific to research[9]). One functional question that arises is: what are the essential metrics within the lists of skills, interests, publications, or comments that are sufficient to identify an individual as the "right person" for a collaborative project?

Although the theory above constitutes what could be termed as a "top-down" approach to deriving scientific opportunities, the tools discussed above could provide information leading to "bottom-up" opportunities or insights as well. For example, an investigator looking for transdisciplinary opportunities could use these tools to establish new research theories (top-down). At the same time, another researcher with a known scientific dilemma might use the tools to understand whether theories, techniques, findings, or molecules from other domains of science could lead to insights and possible experimentation possibilities (bottom-up).

Clearly there are many challenges not only for the development of these new technologies but also in the data that are available for mining and the processes used to identify metrics. However, there seems to be benefit in establishing clear methodology to understand the evolution of scientific interconnectedness, especially as redundancies in systems (i.e., the same DNA sequences found in humans and rats; the innate behavioral fear response in multiple species elicited by snakes) lead to more overlap in research fields. A more firm understanding of scientific readiness combined with the known contextual factors that facilitate and/or hinder transdisciplinary or team science could ultimately assist in the long term establishment and maintenance of successful cross disciplinary teams.

In summary, if transdisciplinary investigation is to be more fully realized, it will be critical to understand the foundation of scientific readiness. The 2006 establishment of the new Division of Program Coordination, Planning, and Strategic Initiatives (DPCPSI) at the NIH offers a central location for NIH to begin to investigate some of the new ideas highlighted above. If facilitative tools are successfully implemented on a broad scale at institutions and agencies, it could help demonstrate scientific necessity for crossing traditional funding and "departmental" boundaries. The cost of establishing and maintaining transdisciplinary teams may to some seem high, but the potential of such research is already evident (e.g., mechanical engineering techniques being applied to the development of artificial organs and limbs). Developing rigorous methods and models may ultimately help researchers and funding agencies/institutions foster new domains of inquiry and new research findings for the betterment of all mankind.

No financial disclosures were reported by the author of this paper.

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